GTZ SUN E Project

Water Boiling and Field Test Results Of Institutional Rocket Stove (Draft)

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September 2008

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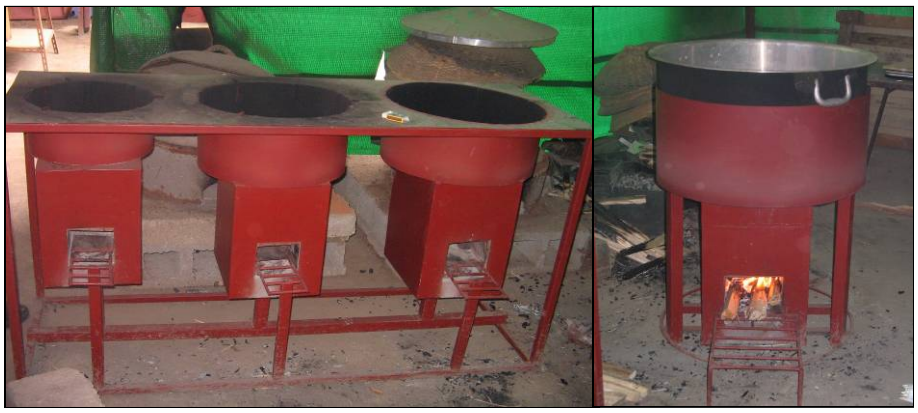
1 Background

In June 2008 samples of institutional Rocket Stove have been locally manufactured with the joint effort of EREDPC and GTZ-SUN Energy Project in Addis Ababa. Four different sizes of such stoves were produced. Three of them are of relatively smaller size supporting pot sizes of 10, 20 and 30 liters. These three stoves were built on one metal frame that holds them all together as one unit. The fourth one is a 100liters capacity stove which was built as a separate unit. The combustion chamber size for the later one can support a pot with upto 120 liters capacity.



The performance of Rocket stoves has been demonstrated in other countries (i.e. Malawi) with a potential of fuelwood saving over 70% compared against traditional wood stoves used in these countries. In Ethiopia, institutions such as hospitals, schools, hotels and restaurants use various types of stoves and fuels. For firewood traditional and improved stoves are available and are currently used by various institutions. It is therefore necessary to compare the performance of a Rocket Stove against these stoves.

The performances of these Rocket stoves have been tested with a series of Water Boiling Tests (WBT) which was followed by field trials in restaurants where actual cooking has been conducted. The results are presented as follows.

2 Water Boiling Test

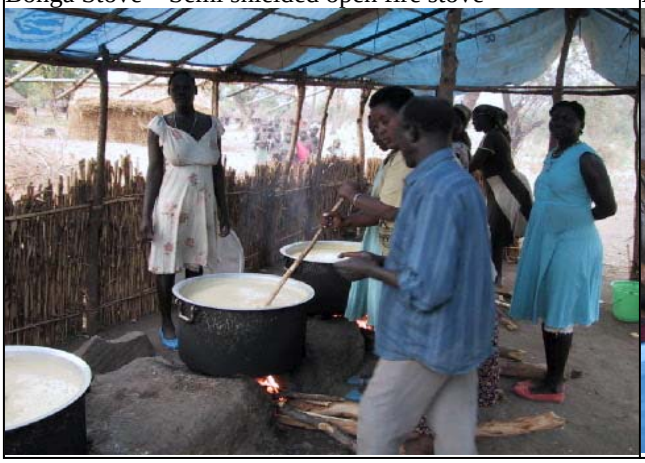
2.1 Test Set up and Procedure

WBT was conducted in a well protected shade available in GTZ SUN Energy Addis Ababa office. The shade was spacious, well ventilated and well covered from wind and rain providing an ideal condition for stove testing. Bundles of split eucalyptus wood was obtained and stored in the testing shade several days before the beginning of the test. When the test began the wood was fairly dried.

Since the testing period was during the main rainy season (i.e. July), the weather condition during testing period varied between wet and cold to sunny and warm days. This could have significant impact on the test results if wood were not purchased in bulk and stored in the shade earlier. Measurements of the wood moisture have been recorded for every test and it was fairly constant varying between 12% and 13% on dry basis.

The test protocol used was that of Aprovecho for WBT. Each test has three phases: a high power test with a cold start and hot start and a low power simmering test. Each test starts with a cold stove with 2/3 of the pot filled with water. When water boils the hot start continues with a pot filled with cold water and let to come to boiling. The test culminates with a 45 minutes simmering time after the hot start test. Measurements of wood consumption, boiling time, water temperature and weather conditions will be noted during each phase of the test. Each stove has been tested three times for their results to be statistically significant.

The performance of the 100liter capacity Rocket Stove was compared with that of traditional stove (Bonga Stove) and another improved institutional stove[1]. However, the test results available for the later two stoves were obtained using a different testing procedure than that used to test the Rocket Stoves. This testing procedure, has only one phase which includes the cold start of the stove followed by a forty-five minutes simmering time with no interruption in between. The comparison with Rocket stove was made by combining the data from the cold start and the simmering phases. This method may not make the two procedures similar but in the absence of data the comparison in this method provides a very good indication about the stoves performances.

Bonga Stove – Semi shielded open fire stove	Improved institutional stove
	

2.2 Results and Discussion

The average of the test results of each stove are summarized in the table below. The efficiency of the Rocket stoves seems to increase with the increase in size of the stove. The efficiency during the high power test is generally higher. With a cold start test, the thermal efficiency was 27%, 35%, 30% and 42% for the 10liter, 20liter, 30liter and 80liter size stoves. As the stove becomes hotter thermal efficiency increases as combustion improves and the stove does not take as much heat as it does when it is cold. Because of these reasons, the high power test with a hot start exhibits a higher efficiency for all stoves.

[1] The stove was tested with 80 liters of water as only 2/3 of the pot was filled. In reality institutions usually fill the pot to the top when they cook. Testing with 80liters of water also gives opportunity to compare the results with other stoves previously tested with similar amount of water.

Test Phases	Units	Rocket Stove Sizes			
		10 L	20 L	30 L	80 L
1- High Power Test (Cold Start)					
Time to boil	min	34.7	42.1	42.5	54.1
Thermal efficiency	%	26.9	35.4	30.5	41.6
Fire power	Watts	5479	6664	10244	20615
2- High Power Test (Hot Start)					
Time to boil	min	21.7	27.5	28.2	41.2
Thermal efficiency	%	31.3	40.7	40.2	48.4
Fire power	Watts	7346	8225	13043	25448
3-Low Power Test (Simmering)					
Thermal efficiency	%	25.6	34.0	27.7	27.4
Firepower	Watts	4338	4980	7931	23860
Turn down ratio		1.3	1.3	1.3	0.9

Comparison with other stoves

One can notice the difference in the thermal efficiency of the Rocket stove with different testing procedures. Calculating the thermal efficiency of the Rocket stove using the same procedure that Bonga and local improved institutional stoves tested helps to put them all in equal level to make the comparison.

Parameters	Unit	Type of Stoves (all tested with 80 liters of water)		
		Bonga-Traditional	Local Improved Institutional	Rocket Stove
Time to boil	min	74	48	56
Thermal Efficiency	%	22.7	32.1	57.9
Firepower	Watts	37561	28957	23801

The locally made improved institutional stove saves up to 30% fuel compared to the traditional Bonga stove. With a Rocket stove however, the saving obtained over the traditional Bonga stove reaches up to 60%.

3 Field Performance

After the Water Boiling Test, the stoves were placed in restaurants for field trial. Because of the rainy season it was difficult to get an institution that uses dry firewood for cooking. Most of these catering establishments do not have enough/extra space to pile up firewood. Because of this it was necessary for the team to find an appropriate place where the stove should be placed and tested.

The 100L Rocket stove was initially put in the kitchen at Hope Enterprise where they prepare food for their feeding centers. However, the cooks didn't like the stove as it was not very powerful as they expected. The main reason for low combustion rate is the high moisture content of wood they use.

The team measured the moisture content on sample firewoods and an average figure of 23% was exhibited. It was necessary for the team to reallocate the stove to a different user.

The 100L Rocket stove was then placed in a restaurant in Merkato that serves over 1000 people per day. The restaurant is open the whole day from 5 AM to 9:00PM. This restaurant buys fuelwood in bulk and stores in the shade. The wood they use is quite dry with moisture content not exceeding 15%.

Existing cooking place	Cooking with Rocket Stove
	

The project team demonstrated the way the Rocket stove should operate including fire lighting and fuelwood management. After four days of learning period, the cook in the restaurant took measurements of wood consumption of the Rocket stove in comparison with an equal sized existing fireplace for the same activity. It was reported by the cook that the existing stove consumes 14 bundles of dried firewood while the Rocket stove consumes only 4 bundles for the same activity. This is a fuel saving of over 70%. The feedback about the stove from the cooks and the restaurant owner is great. Now, the owner wants to replace all stoves, wood stoves and kerosene stoves, with Rocket stoves when they become available in the market.

The other three stoves, 10L, 20L and 30L size, are placed in another restaurant. Measurements have not been taken during the rainy season even though the cooks use the stoves. Fuel consumption measurements will be taken by the cook for comparison when dry wood is available.

4 Observations

During the WBT and later in the field the team has noted some points that need further consideration:

- Wood rack at the fuel inlet is not stable in the small size Rocket Stoves (Size 10L to 30L). Increasing the width of the rack and putting two support points underneath instead of one could make it more stable.
- Door size on small size Rocket stoves might be too small to accommodate the type/size of wood mostly available and used in Tigray.

Annex – Test Data

Rocket Stove Type (Size)		10 L stove		20 L stove		30 L stove		100 L stove	
1. HIGH POWER TEST (COLD START)	**units**	**Average**	**St Dev**	**Average**	**St Dev**	**Average**	**St Dev**	**Average**	**St Dev**
Time to boil Pot # 1	min	34.7	11.4	42.1	8.3	42.5	9.4	54.1	1.5
Temp-corrected time to boil Pot # 1	min	35.5	11.7	43.3	8.8	43.7	10.5	54.5	0.7
Burning rate	g/min	17.4	3.7	21.2	5.1	32.6	6.3	65.7	9.2
Thermal efficiency	%	27	5	35	2	30	3	42	1
Specific fuel consumption	g/liter	86.6	13.6	60.0	7.2	59.2	3.6	48.7	7.5
Temp-corrected specific consumption	g/liter	88.8	14.0	61.5	6.2	60.8	4.6	49.2	8.3
Firepower	watts	5479.2	1168.5	6664.4	1596.3	10243.6	1986.7	20615.3	2880.7
2. HIGH POWER TEST (HOT START)	**units**	**Average**	**St Dev**	**Average**	**St Dev**	**Average**	**St Dev**	**Average**	**St Dev**
Time to boil Pot # 1	min	21.7	5.9	27.5	6.5	28.2	1.0	41.2	5.6
Temp-corrected time to boil Pot # 1	min	23.1	6.5	28.6	5.8	29.4	2.0	43.3	6.2
Burning rate	g/min	23.4	4.6	26.2	2.2	41.5	6.0	81.0	10.7
Thermal efficiency	%	31	1	41	3	40	9	48	2
Specific fuel consumption	g/liter	73.9	7.9	48.9	7.7	52.5	5.7	46.2	0.9
Temp-corrected specific consumption	g/liter	78.5	9.6	50.9	6.5	54.7	3.9	48.5	0.2
Firepower	watts	7345.6	1455.9	8224.9	705.7	13042.6	1881.0	25447.9	3351.4
3. LOW POWER (SIMMER)	**units**	**Average**	**St Dev**	**Average**	**St Dev**	**Average**	**St Dev**	**Average**	**St Dev**
Burning rate	g/min	13.8	0.9	15.9	1.5	25.3	4.0	76.0	12.8
Thermal efficiency	%	26	2	34	4	28	15	27	3
Specific fuel consumption	g/liter	114.0	11.7	52.6	5.7	56.7	10.9	42.7	12.5
Firepower	watts	4338.4	273.2	4979.5	466.2	7931.1	1268.8	23860.2	4020.5
Turn down ratio	--	1.3	0.3	1.3	0.2	1.3	0.1	0.9	0.2